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16367 U.S. PTO
07/31/03

PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a r quest for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR §1.53(c).

17518 U.S. PTO

INVENTOR(S)

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Additional inventors are being named on the 0 separately numbered sheets attached hereto

TITLE OF THE INVENTION (500 characters max)

Determining Distances in a Warehouse

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Address					
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Country	United States	Telephone		Fax	

ENCLOSED APPLICATION PARTS ***(check all that apply)***

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[X] Drawing(s) *Number of Sheets* 9 [] Other (specify)

[] Application Data Sheet. See 37 CFR 1.76.

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[X] A check or money order is enclosed to cover the filing fees.

[] The Director is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: 06-1050

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

[X] No.

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Respectfully submitted,

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Date July 31, 2003

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Docket No. 13915-055P01 / 2003P00494 US

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PROVISIONAL APPLICATION FOR PATENT

under

37 CFR §1.53(c)

TITLE: DETERMINING DISTANCES IN A WAREHOUSE

APPLICANT: THOMAS CHRIST AND RALF SCHRAENKLER

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Determining Distances in a Warehouse

Description

Field of the Invention

The invention relates to warehouse management.

Background of the Invention

In warehouse management it is often necessary to determine the shortest distance a resource has to travel through a warehouse when moving from a location A to a location B. This can be one of the objectives of a Task and Resource Management System (TRM) for warehouse operations. In order to determine the distance the system needs to know the distance for every pair of locations. Locations may be storage bins, high bay racking zones, pallet zones, loading and unloading zones, etc. For increasing numbers of locations, determining distances soon gets very difficult. For example, to determine distances one would need to type in 1.000.000 distances for a warehouse with only 1.000 bins.

Brief Summary of the Invention

In order to avoid disadvantages like manual input of all the distances, a mechanism is provided that divides the problem in smaller sub-problems and puts the solutions of the sub-problem together to obtain an overall solution.

Locations are grouped together in zones. A zone can be, for example, a group of storage bins. In a high rack storage this can be for example an aisle. Thus, there can be a source storage bin belonging to a zone and a

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destination storage bin belonging to another zone. For every zone at least one entry and one exit point or node is defined. The function of an entry node and an exit node may provided by a single node. Every storage bin can be characterized by (preferably x, y, z)-coordinates.

In one embodiment of the invention, the actual routing is performed in three steps. In the first step a route from a source storage bin to an exit node of the zone is determined. This step may be referred to as "intra zone routing". The intra zone routing can be done based on a metric. The metric may be one of Euclidian metric, Manhattan metric or any other metric that is suitable to describe distances for the respective zone. The distance from the source bin to the exit node is determined using the metric that has been defined for this zone. In different zones different metric may apply. In the second step the distance from the source zone to the destination zone is determined. This step may be called "inter zone routing". The inter zone routing may be done using a "line-of-sight method". In this method, the basic assumption to simplify the determination of distances is that there is a line-of-sight between an exit node of the source zone and an entry node of the destination zone. For exceptions so-called "obstacles" can be defined. If there is no line-of-sight, because there is an obstacle, this obstacle can be defined in the system and the mechanism then determines the distance, taking into account that the resource has to travel around the obstacle. Obstacles may be defined with two edges (e.g. wall) or four edges (e.g. rectangle). The third step consists of determining the distance from the entry node of the destination zone to a

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destination storage bin. This is again an "intra zone routing" as described in the first step. In the case the destination zone is an exit of the warehouse, for example a loading and unloading zone, the third step has not to be performed or results in a zero distance. It may happen that the source destination is an entry point into the warehouse. Accordingly, the first step has not to be performed or results in a zero distance.

For the above example with 1.000 bins, the user does not have to type in the 1.000.000 distances between the bins. He just has to group them to zones and to define the entry/exit nodes of these zones. If there are obstacles on the shop floor of the warehouse, he additionally has to define these obstacles. All the rest is done using the defined metrics and the line-of-sight method.

Details of one or more implementations are set forth in the accompanying drawings and the description below. Other features and advantages may be apparent from the description, the drawings, and the claims.

Brief Description of the Drawings

Figure 1 shows a view of an exemplary model warehouse.

Figure 2 shows an exemplary route in the warehouse of figure 1.

Figure 3 shows the floor plan of the exemplary model warehouse of figure 1.

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Figure 4 shows the exemplary model warehouse of figure 1 mapped to the node/zone concept.

Figure 5 depicts the different steps in the route determination.

Figure 6 shows an exemplary definition of an exception for route calculation.

Figure 7 shows an example for calculating mandatory routes.

Figure 8 shows the services provided by the Route in a table.

Figure 9 shows a diagram of basic interaction between the three processes together with the respective services.

Detailed Description of the Invention

Referring now to the drawings, in which like numerals represent like elements throughout the several figures, aspects of the present invention and the exemplary operating environment will be described.

Figure 1 shows a view of an exemplary model warehouse with a goods entry zone with 3 doors, a bulk storage area, two high rack storage types, a fixed bin storage type for picking, a conveyor, a sortation loop, some work centers, a couple of P&Ds, and a goods issue zone with 7 doors.

One basic assumption of our approach is that "what is not forbidden is allowed". So if you want to move from a

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to A to B, we just calculate the distance between these two coordinates by using the predefined metric. Only if there is a problem, for example there is an obstacle in between, the routing algorithm has to be more refined.

First the system tries to determine a route according to the predefined metric. If there is an obstacle in between, the system recognizes this and calculates a route via the edges of the obstacle (line of sight).

Figure 2 shows one example of a route in the warehouse of figure 1.

Another reason for not just taking the direct route (using the metric) may be a forced P&D. This means that for some reason or another there has to be done for example a packing operation. The system then first calculates the route to the appropriate packing station and from there to the original destination.

In the case where the movement has to be done in a rather strange shape, we have the possibility to enter the distance between two points in an exception table.Figure 3 shows the floor plan of the exemplary model warehouse of figure 1. First a metric is defined for the whole warehouse or for special zones within the warehouse. In an aisle for example we may use the Manhattan metric whereas in the rest of the warehouse the Euclidean metric is used.

To describe the rest of the objects apart from the WM storage bins, we use entities called nodes. Nodes may be either logical or physical or both.

A logical node is only used for the routing algorithm. It is just a logical construction. On a logical node nothing can be stored or put down. Examples for logical nodes are the entry and exit points of aisles or the edges of an obstacle.

A physical node serve for the routing as well as for storing goods. Examples are P&Ds.

Within a node we can distinguish between entry and exit or bi-directional nodes or nodes that are neither entry nor exit nodes (obstacles).

Objects like walls or storage types are defined as obstacles for the routing algorithms.

Figure 4 shows the exemplary model warehouse of figure 1 mapped to the node/zone concept. For example we may have:

a physical entry node, representing one of the doors of the goods receipt area,

a physical exit node, representing one of the doors of the goods issue area,

a logical node representing an edge of the fixed bin storage type as an obstacle,

an entry and exit node for the fixed bin area,

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some other warehouse zones, like the bulk zone or some zones within the high rack, and

the P&Ds and the conveyor or sortation loop.Figure 5 depicts the different steps in the route determination from source A to destination B. First we determine the exit node of the source zone, then we check if there is a dedicated P&D for the source zone. Then we check whether one of the free P&Ds should be taken into account. Free P&Ds are P&Ds that are not dedicated to a specific zone. Then we make the same checks for the destination bin, we look for dedicated P&Ds for the destination zone, for the entry node of the destination zone, and al last for the destination bin. The restrictions in this example are that the whole route must be able to carry E1 pallets, that the start of the route must be done by a resource that can reach the source level and that the end of the route must be done by a resource that can reach the destination level.Figure 6 shows an exemplary definition of an exception for route calculation. Whereas the narrow aisle forklift can pass through the narrow aisle, the standard forklift has to make a detour. The distance will not be 10 meters but 15 meters instead. The exceptions can be defined per route (source node / destination node) and resource type. Routes can also be completely disabled.Figure 7 shows an example for calculating mandatory routes. Mandatory routes can be treated as exceptions. They force a route to be constructed via a specific node (e.g. P&D, Work Center). For example all the pallets that are sent from the high-rack storage to the goods issue area have to be shrink-wrapped. So they will be sent via the shrink wrap machine to the goods issue

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area.Figure 8 shows the services of the Route Management for the other packages. There are:

Get list routes: This gives a list of all the possible routes to the caller.

Get list prioritized WC by route: this gives a prioritized list of all the possible work centers to the caller.

Get list distance: This gives the distance of a specific resource to different source locations (e.g. useful for task interleaving).Figure 9 depicts all the three processes together with the services according to the process model.

To summarize:

Route Management has the control over the areas:

· Zone to zone (inter zone) parameters and metric

Overall (inter + intra) zone routing calculations, based on defined metric and taking into consideration any defined exception

Nodes with their attributes

Dedication of nodes to zones

Enforcement of mandatory routes (i.e. passing via zone)

Compute weighted cost of Resource Type's movement, given the calculated duration and execution qualifications preferences

Computing the weighted cost of the movement means, that it does not only take into account the calculated distance between two points but also the duration (via the velocity of the resource) together with the execution preferences, i.e. some routes may be more appropriate to a specific resource than others (ex. In a narrow aisle, only the narrow aisle forklifts are allowed to move).

The Resource Management manages all the master data related to workers, devices and Resources in the warehouse. Additionally, it has the visibility over dynamic Resource information (e.g. statuses). This information enable keeping track of all Resources currently present/active in the system, thus enables control of Resources.

The package has the following roles:

- Resources administration
- Manage all the information associated with Resources

The package has a control over the following areas:

- Qualifications
- Resource characteristics (e.g. Velocity (x, z))

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- Audit trail (i.e. Resource 'BOM' history and statuses)

The Site Map Management package has a comprehensive visibility of the warehouse. As such, it manages the following Site Map information:

Bins (e.g. storage bin, Work Center (WC), Pick-up & Drop-off points (P&D))

Logical and physical bin groupings (e.g. zones)

Bin content & capacity

Routes with associated information (e.g. duration, priority etc.)

The package is comprised of two subsystems:

- Bin Management
- Route Management

Bin Management manages information associated with physical floor entities and their logical groupings.

The subsystem roles are:

- Manipulates bins to zones/coordinates for navigation purposes

- Prioritizes Work Centers based on the required operation

Bin Management has a control over the following areas:

- Bins and coordinates
- Zones
- Capacity & content
- Work Centers' roles

The Route Management manages route information and provides cost/priority calculations.

The routes and their cost calculations, which are based on route, bin and Resource Type aspects aim to support decision-making concerning Task creation and selection.

The subsystem roles are the following:

- Manages route information (e.g. P&D dedications, metrics, Nodes' attributes)
- Manipulates storage, Resource capabilities and preferences to routing terms

- Provides cost/priority calculations based on the defined metric

The Route Management manages the route information (e.g. P&D dedications, metrics, nodes' attributes). It manipulates bin, resource capabilities and preferences to routing terms and it provides cost or priority calculations based on the defined metric.

Route Management has the control over the following areas:

- Distances between Nodes
- Zone groups
- Calculation metric

Resource Element Type stands for role definition in the warehouse. It is used to define the required roles for Resource Type's construction, which are eventually compared with the allowed Resource Element Types of the Resource Element, whenever the construction takes place. The Resource Element Type (the role) is determined for each Resource Element, as soon as it was logged on successfully to the system.

The main characteristic of the Resource is its Resource Type. The Resource Type has its own identification and description (e.g. „forklift") and a set of other properties.

The Resource Types can be dived into 2 basic categories: Multi-Resource Element Type and Composite Resource Type.

- Multi-Resource Element Type - Resource Type is a constitution of Multi- Resource Element types, which can belong to the same/different Resource Element Types. For example, Resource Type can be composed of a team, consisting 5 forklifts and 5 drivers. In that case, the warehouse administrator chooses not to manage them as Composite Resources (refer to Composite Resource Types).

- Composite Resource Types - A Composite Resource Type is a Resource Type, which is combined of one or more other Resource Types. A composite Resource Type allows Resources to be organized in a hierarchic structure. The granularity of such structure depends entirely on the configuration chosen.

Resource Element represents the workers and the devices in the warehouse. These are Elementary components, of which a Resource is composed. The differentiation between workers and devices is made to determine the required information and the system (i.e. HR/PM) TRM should access to get the information from. The same differentiation is required for similar reasons for TRM inbound interactions from external systems.

Qualifications determine the capabilities of the Resource Elements and Resource Types. There are two types

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of qualifications, which are selected to be used depending on the time related to the logon milestone:

- Logon Qualifications
- Execution Qualifications

The Logon Qualifications determine the skills (or roles) for Resource Elements, which are being checked against in the logon process. They are used up to the point when the Resource Element was successfully logged on to the system.

Execution Qualifications are used from the point the Resource has logged on to the system, until its logoff. They define the capability and preferences of performing a certain Task based on its properties (e.g. Working Area, levels, Handling Unit Type). The Execution Qualifications deal with execution perspective and as such, they remain always active (they are not logon dependent) for Resource Type, throughout its life.

Resource construction is based on the determined resource type. Once the Resource construction has been accomplished by logging on all the required resource elements that satisfy all the resource element types, an identification number is assigned to it. It should be noted that in the future, the option that enables logging on to a specific Resource would be considered.

As soon as the Resource is created, it inherits all Resource Element attributes along with the Resource Type's

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attributes and all its actions and statuses are being tracked from now on.

It is possible to build a Resource in a hierarchic manner by constructing a Composite Resource. The Composite Resource has a corresponding Composite Resource Types.

Note that in first delivery Construction of Composite Resource will not be supported.

Resource profile is comprised of user preferences, device capabilities, Worklist size, Task release strategy, ability to execute clustered and interleaving Tasks and notification agent parameters.

The Route and Bin subsystems' data model are represented together since:

- They are both strongly related to each other
- The Bin Management has (almost) no proprietary entities

Node: The various warehouse nodes' information. In addition to the geographical location of the nodes, this entity defines their type and behavior.

Zone: This entity concentrates the Zone related information. One of its most important Tasks is to save the intra zone properties, such as the metric used for distance calculation.

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LAGP: This LES' table maps bins onto their Zones to achieve another grouping for routing purposes. In addition, this table is to contain geographical location of the bins as well as sequencing information.

Zone - Node dedication: Each node may serve one zone (or more) as an entry/exit point and one zone may be served by several nodes. This entity contains this cross-referencing information.

Obstacle: This table maps physical obstacles within the warehouse onto nodes. Each obstacle serves as input for the connectivity graph (i.e. nodes connected by line of sight).

Neighbor Nodes Distance: By combining the node and obstacle tables together, the neighbor table could be derived. This oriented graph represents pairs of connected nodes. Any pair of nodes is checked against the obstacle table to ensure the existence of Line of Sight.

Inter-Route exception: Using the metric defined across TRM, the distance between pairs of points can be calculated. This entity (positively) defines exceptions to the above rule. This table is Resource Type related, namely, the exception in the distance calculated between a pair of nodes could be attached to a specific Resource Type.

Routing Table: This entity represents the 'shortest path' between any two nodes in the warehouse. The Neighbor Nodes Distance table, together with the Inter-Route

Exception table, is used as the input for the Routing table. The above pre-calculation is skipped for logical pairs that contain logical nodes that are not served as either entry or exit points.

Mandatory Routes: This entity enables degeneration of the routing model for special purposes by overruling the Routing table information. Mandatory Route may be defined (as a configuration) between any pair of zones.

Transactions

Get List Routes

Import: HU information, move information and Resource Type list (optional)

Export: Next destination set, prioritized Resource Types per each destination

Get List Prioritized WC by Route

Import: Move information, Work Center list, and HU information (optional)

Export: Prioritized Work center list

Get List Distances

Import: Source location, Destination list and Resource information

Export: Prioritized (by distance) destination list

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Modules

The whole warehouse complex may be represented as ***zones*** connected by ***routes***. The zones are similar to (and in many cases the same as) LES' storage types. However, it is preferable **not** to use an external subdivision for internal purposes, since there is no guarantee that it will always fit into our needs. Aisles are strongly related to Resources abilities, and thus will be mapped onto zones. That is to say, all the bins belong to an aisle will be pointing to the same zone identifier.

Nodes are abstract entities used to enable easy configuration and calculation of routes. The nodes may represent both physical entities (e.g. P&D locations) and logical ones (such as zones' entry/exit points).

Any movement is then defined between pairs of source bin/node and destination bin/node.

<u>Get List Routes</u>

As mentioned, Task Management invokes this service in full scale on Task creation phase. In return, Route Management sends back a list of optional tasks' routings. Nonetheless, the choice of the particular routing option will be left to the caller.

Task Routing refers to the 'next step' suggested rather than the whole (source to destination) path. Namely, the Route management suggests all the sub paths that eventually lead to the required destination. However, the path as a whole is a special case in its sub-path set.

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This chief module serves all the above listed Transactions. In the most general case, it receives source, destination, and HU type to be moved. As output, the module will provide possible routes with a list of corresponding Resource Types. Each pair (Route-Resource Type) has its own priority, which expresses the overall (estimated) cost of the route along with the Resource Type preferences to execute the suggested task routing.

To allow future use of external routing engine, the Route Management must be configurable separately from all the rest of the TRM system. It may "know" most of the entities used in the TRM system (Resource Type, Bin etc), but the TRM must not know any of the routing internal entities.

Function Modules

Routing Algorithm

The Routing algorithm uses the Roadmap approach, which is based on 2 layers: intra-zone (city map) and inter-zone (highway paths). While intra-zone refers to movements inside aisles, the inter-zone navigation represents movements between aisles.

Any movement within the warehouse can be considered as a superposition of intra and inter zone movements. Therefore, it can be calculated using the above-mentioned algorithms. The entry/exit nodes of zones define the tangent boundaries between the two routing algorithms.

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Since only the *next* step must be returned, the procedure must first consider all movement possibilities from source. Thereafter, for each 'next step' calculated, the Rest of Trip cost (ROT - movement from the current 'next step' to destination) has to be estimated. The overall cost (to 'next step' together with the ROT) serves as a common denominator to evaluate the different Routings suggested.

Note the difference between 'next step' **calculation** and ROT **estimation**. The first refers to a specific Resource Type; the latter is somehow independent of Resource Type, since it will be determined in the future. The ROT estimation is based on an abstract Resource Type, which represents an average cost of all the available Resource Types.

<u>Intra Zone Routing</u>

Intra Zone routing is defined as one of the following movements:

- From a bin to the zone's exit nodes
- From a zone's entry node to the zone's bins
- Moves within a zone

The model uses the information placed within LES' LAGP and the zone information (local metric) to calculate the cost of these internal moves. The intra-zone

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calculations are done on the fly, to avoid pre-calculated intra-routes avalanche.

Inter Zone Routing

Movements between Zones are handled using the inter-zone algorithm. To avoid excess of paths, logical nodes were used. Unlike physical nodes, the logical ones serve as junctions and thus do not necessarily represent places where HUs may be placed.

The relationship between adjacent nodes (neighbors) is described using a directed graph. This data model may easily serve as a basis for optimized path calculation between any pair of nodes. Nonetheless, this procedure is both time-consuming (and generally time-boundless). To allow fast lookup, all the possible movements (from physical nodes to physical nodes) are pre-calculated per each Resource Type.

Get List Prioritized WC

This special case of the general Routing mechanism aims to solve the cases where no concrete intermediate destination was predefined. Aside of source and destination, this Function Module receives a set of possible locations through which (one of them) the Route may pass. Good example is a requirement to move HU from source to destination via a Value Added station (e.g. shrink wrap machine). This procedure usually serves as preliminary stage to the Routing phase, for it determines the (best) intermediate location to serve as temporary destination.

Invoking the rough cost estimation of moving from source to destination via the various intermediate locations, enable the latter's prioritization.

Get List Distances

This is a degenerated case of the Routing algorithm, which uses only the distance calculation between pairs of nodes/bins. It is used to better prioritize tasks for a specific Resource according to the latter distance from the tasks' sources.

Transactions

Administer Request

Import: Request

Export: Confirm administration

Update Request Life Cycle

Import: Task execution data

Export: Confirm update

Get Detail Execution Data

Import: Tasks

Export: Execution data

Modules

Request Administrator:

Request Administrator validates the Request information and manages references to requests along with their normalized priorities. It is responsible for the Request life cycle and for providing confirmations to LES based on the required confirmation method.

Function Modules

Scheduler:

The Scheduler is the ultimate Request release controller. It checks the requests continuously, upon Task confirmation or submission of a new Request. The Scheduler provides the following release related answers based on priorities, grouping and dependencies: When, What and How (release in groups. e.g. merging aspects).

The answer to "When" and "What" deals with scheduling issues that aim to increase the efficiency in the warehouse. The scheduling mechanism releases requests for execution as late as possible, using Request weighted priorities and comparing them to Task priorities (within the Task pool). The release control reduces the number of Tasks within the system and limits the pool just for high priority Tasks. Moreover, by postponing release of requests for execution until the last moment (close to execution), better decisions can be made regarding Task creation.

The answer to "How" deals with merging issue. There is a m:n relation between Request and Task. Several Request Items may be translated into one Task and one Request may be translated into many Tasks. The Scheduler wraps the Request Item(s) to assure the appropriate Task creation. At the first stages of each picking, every Request Item is treated as a separate Task. Thereafter, when the picked materials are to be moved together, the Scheduler will merge them together to assure creation of only one Task.

The optimization roles are satisfied by an internal standard optimization algorithm, but might as well be satisfied by utilizing the provided capability to integrate external scheduling engines.

Abstract of the Disclosure

The invention relates to warehouse management. In warehouse management it is often necessary to determine the shortest distance a resource has to travel through a warehouse when moving from a location A to a location B. To determine distances the locations are grouped together in zones. For every zone at least one entry and one exit point or node is defined. The function of an entry node and an exit node may provided by a single node. Every node is by its coordinates (preferably x, y, z). The routing is performed in three steps. In the first step a route from a source storage bin to an exit node of the zone is determined. This step may be referred to as "intra zone routing". The intra zone routing can be done based on a metric. In the second step the distance from the source zone to the destination zone is determined. This step may be called "inter zone routing". The inter zone routing may be done using a "line-of-sight method". The third step consists of determining the distance from the entry node of the destination zone to a destination storage bin. This is again an "intra zone routing" as described in the first step.

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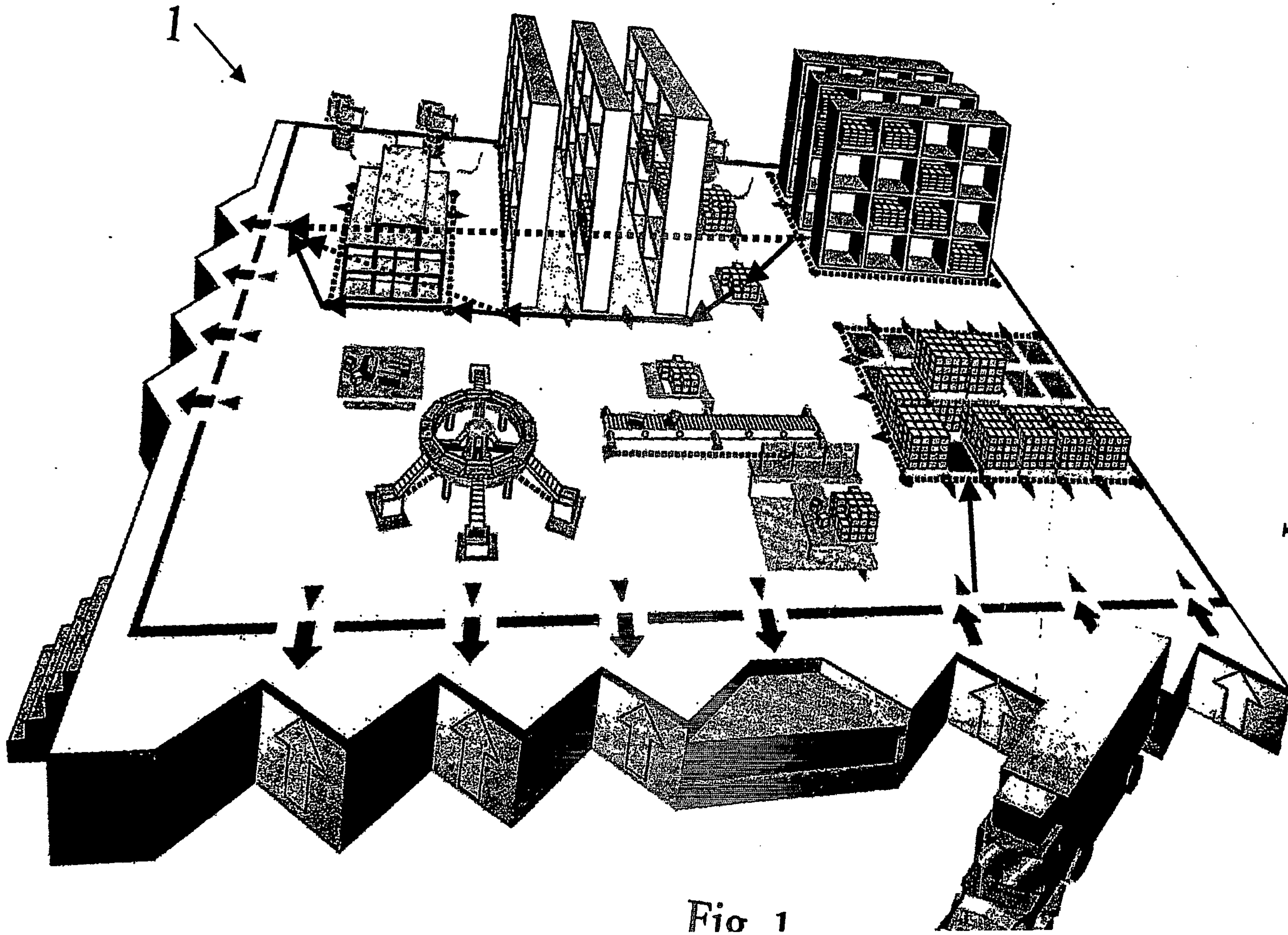


Fig 1

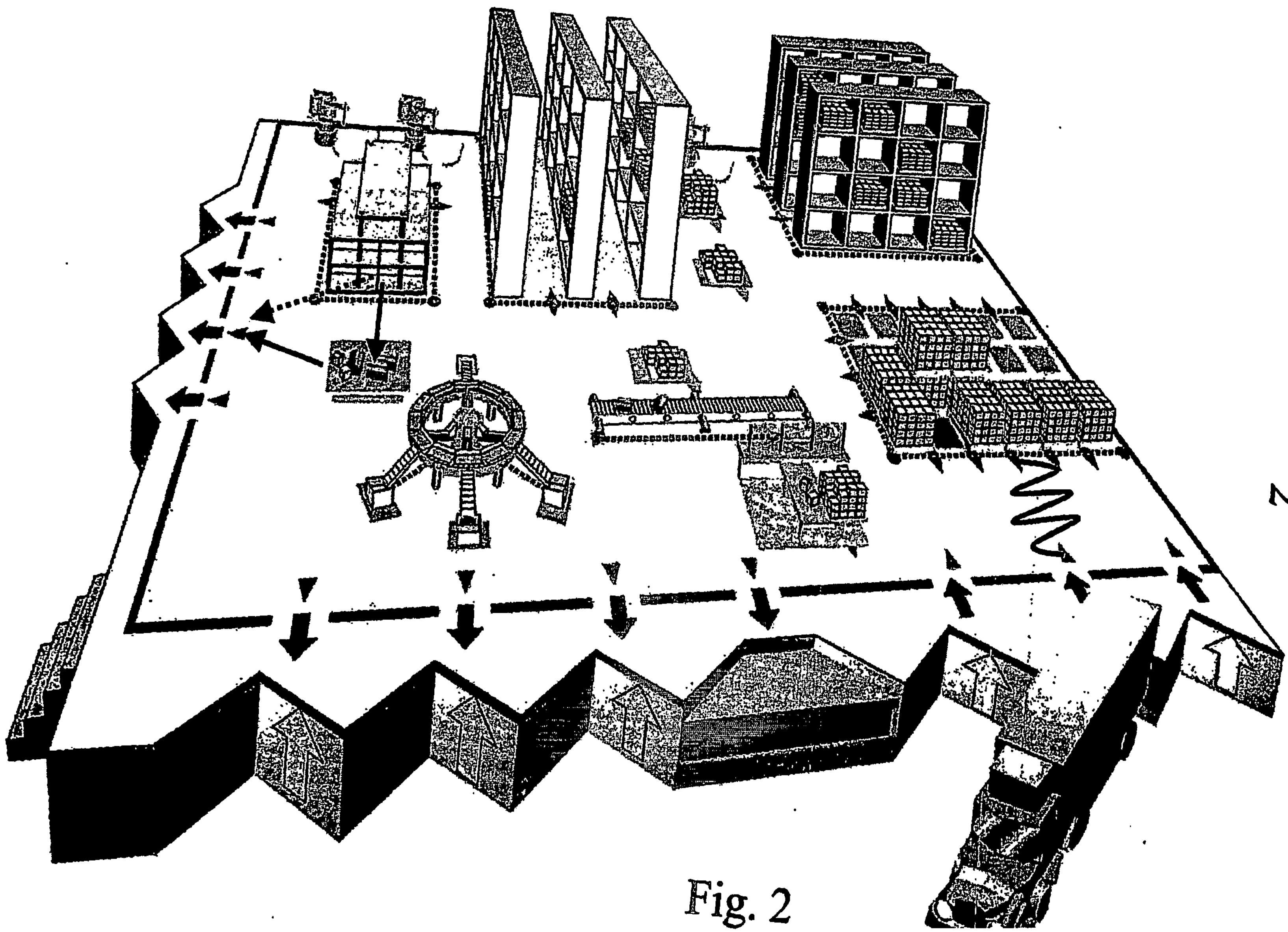


Fig. 2

3

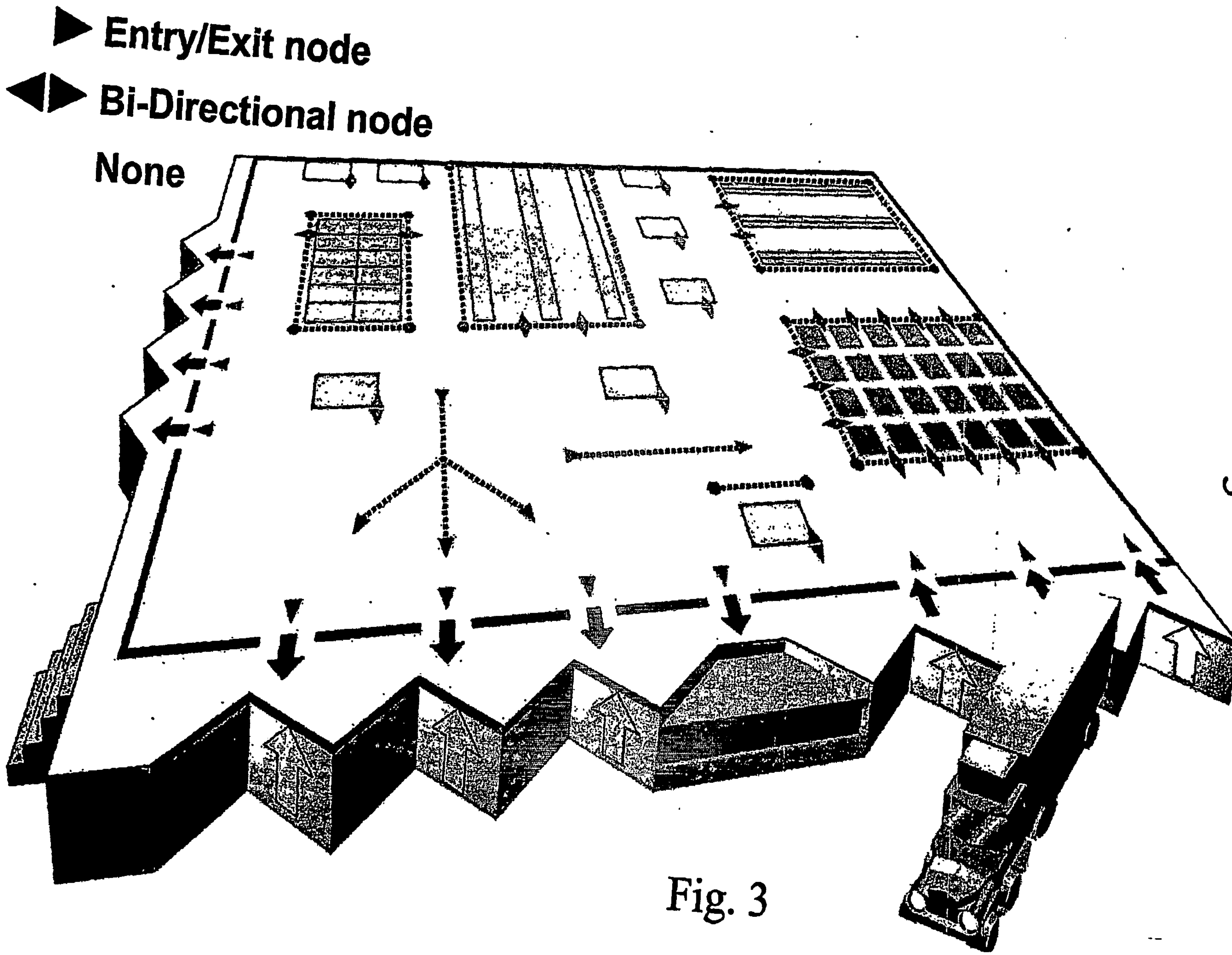


Fig. 3

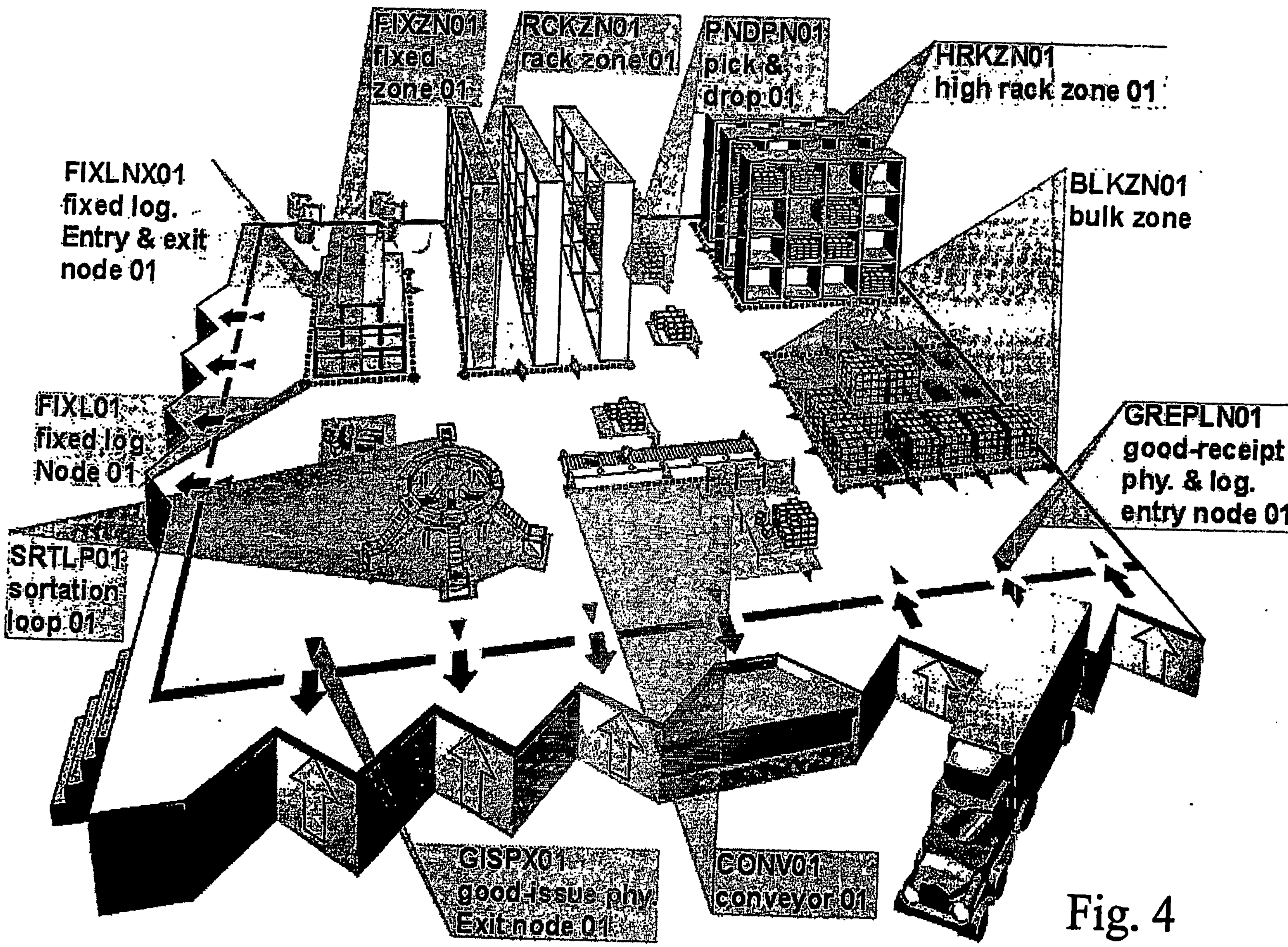
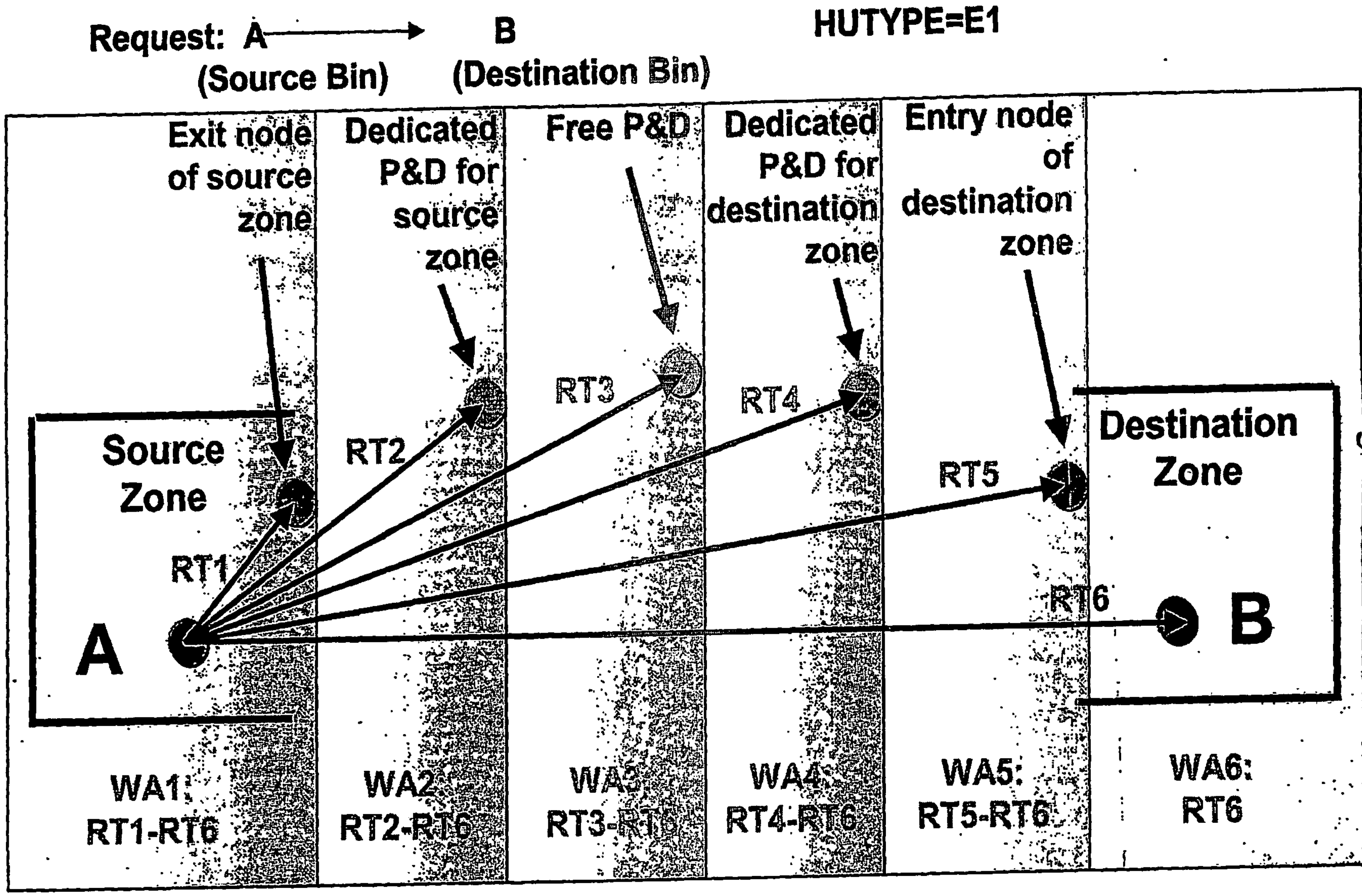

FIXZN01
fixed
zone 01
RCKZN01
rack zone 01
PNDPN01
pick &
drop 01
HRKZN01
high rack zone 01
FIXLNX01
fixed log.
Entry & exit
node 01
BLKZN01
bulk zone
FIXL01
fixed log.
Node 01
GREPLN01
good-receipt
phy. & log.
entry node 01
SRTLP01
sortation
loop 01
GISPX01
good-issue phy.
Exit node 01
CONV01
conveyor 01

Fig. 4



- RT1-RT6 can carry E1 HUTYPE
- RT1 can reach level of source bin
- RT6 can reach level of destination bin

Fig. 5

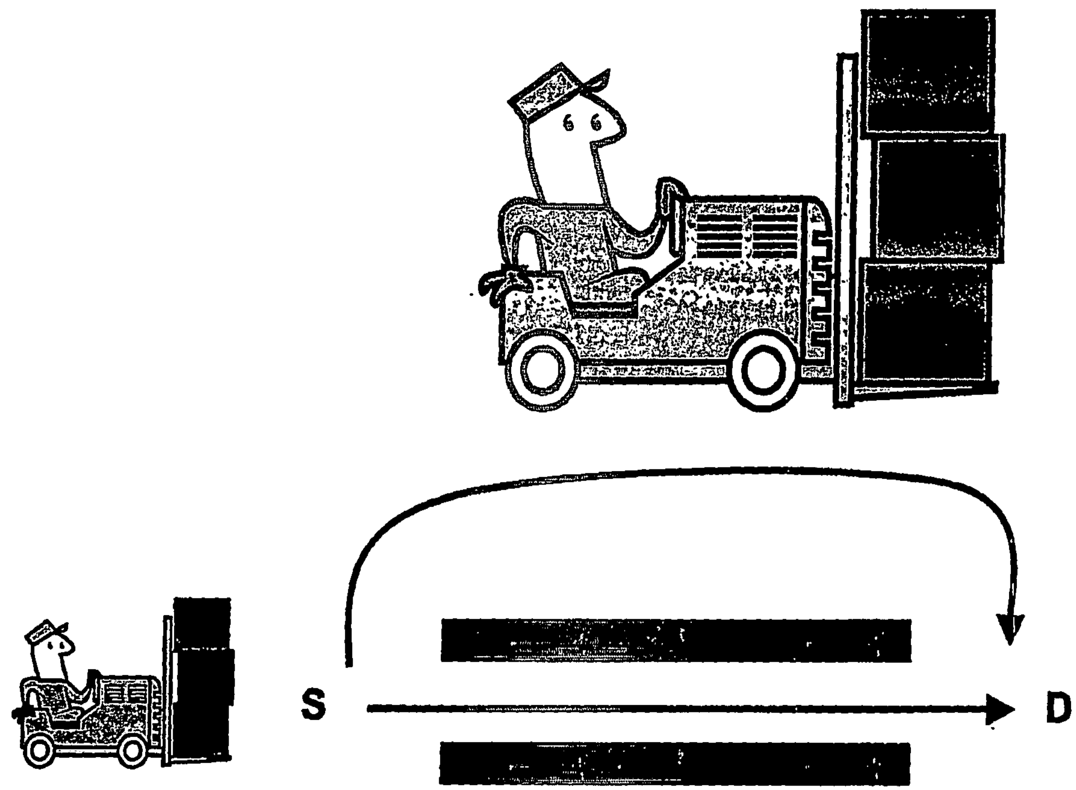


Fig. 6

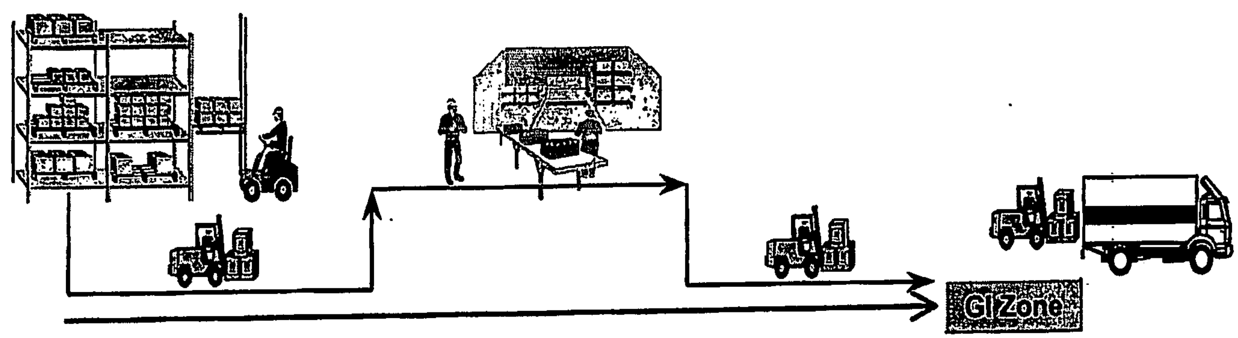
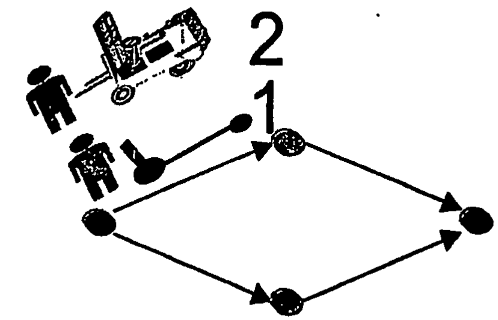


Fig. 7

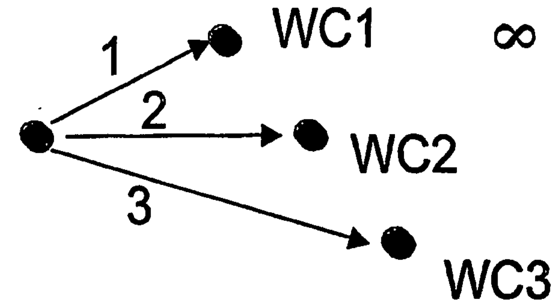
Get list routes

Used in Use-Case: Execute Request
Caller: Task Management
Goal: Determine and prioritize the routes, in which the required movement can be carried out.



Get list prioritized WC by route

Used in Use-Case: Execute Request
Caller: Task Management
Goal: Prioritize Work Center set (intermediate destinations) based on routing cost computation



Get list distances

Used in Use-Case: Execute Request
Caller: Task Management
Goal: Calculates the distance from a specific Resource to a set of source locations

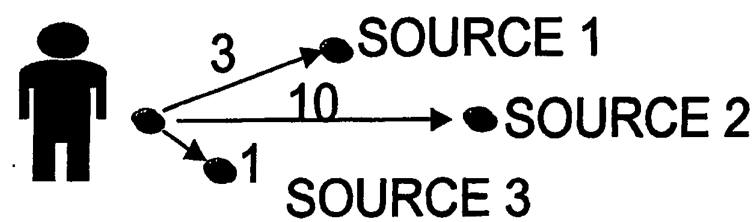


Fig. 8

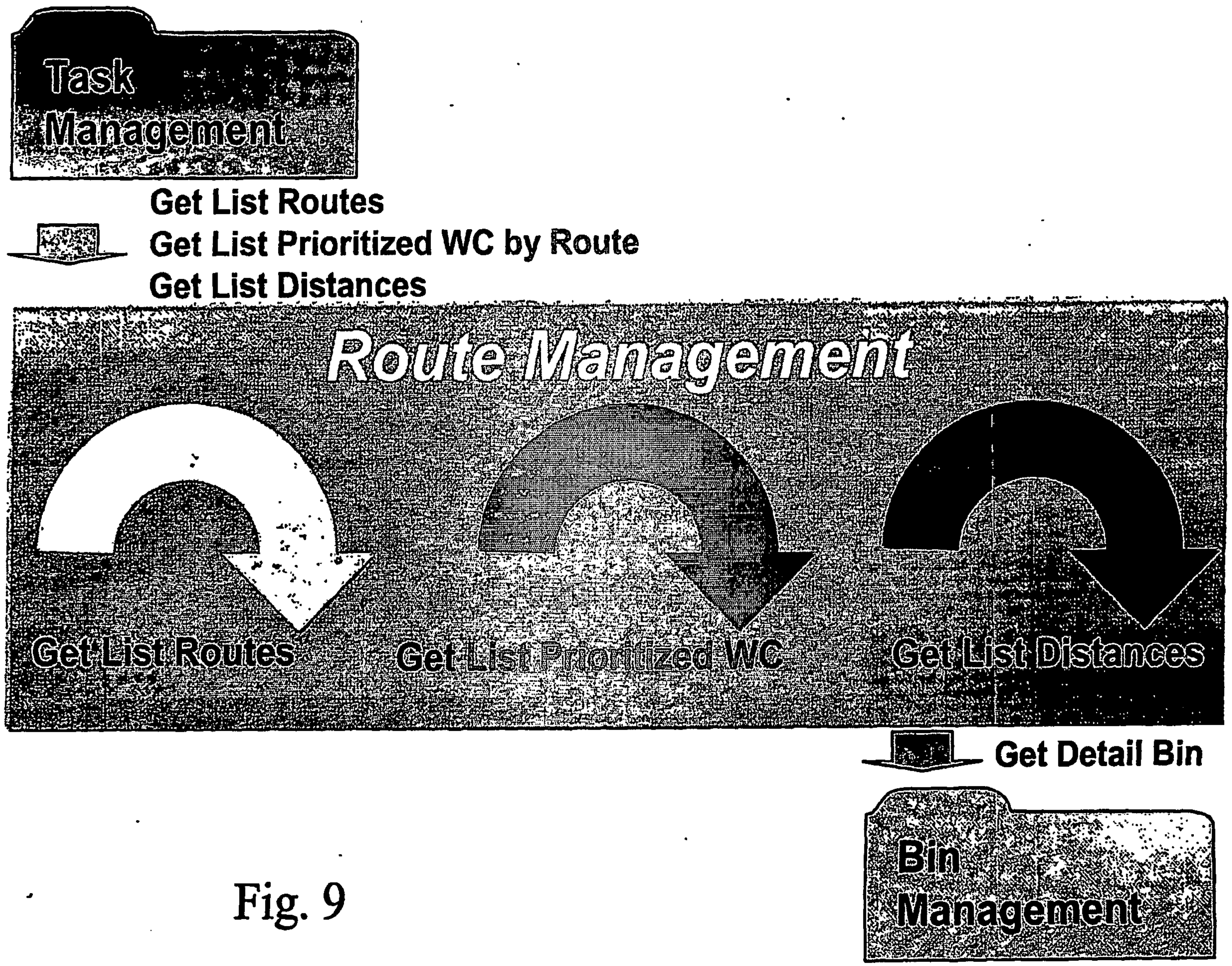

Task
Management
Get List Routes
Get List Prioritized WC by Route
Get List Distances
Route Management
Get List Routes
Get List Prioritized WC
Get List Distances
Get Detail Bin
Bin
Management

Fig. 9

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